USING A HABDUINO FOR TELEMETRY IN ARCTIC ATMOSPHERES AS A HANDS-ON SPACE EDUCATION PROJECT FOR SECONDARY SCHOOL STUDENTS

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ABSTRACT

The HABduino project is an open source shield for the Arduino Uno. The main purpose of the HABduino is to send the position and altitude of a high-altitude balloon with radio telemetry.

Although the HABduino was not developed to send custom data, students from secondary school Stedelijke Humaniora Dilsen managed to adjust the code so it could send their own data from a high-altitude balloon flown above the Norwegian archipelago Svalbard.

The main scientific purpose of the project was to determine the altitude of the tropopause in an arctic atmosphere. A temperature sensor and a humidity sensor were used to achieve this goal. The measurements were sent to the HABduino via serial communication before sending them to the receiver. Two balloons were used to reduce errors.

1. LAUNCH IN SVALBARD

One obvious reason to opt for the Norwegian archipelago Svalbard as a launch site is the almost complete absence of air traffic. Another reason is the possibility to carry out a radiation experiment to study a possible correlation between atmospheric gammas and latitude, as described in [1].

Figure 1. Seven students of Stedelijke Humaniora Dilsen, known as Deezers, and their teacher after successfully tracking both payloads.
From left to right: Simon Paradijs, Deyan Marolt, Wouter Coenen, Jarne Dijkmans, Simon Rutten, Sander Vuurstaek, Bram Creusen and Dirk Geeroms.

Figure 2. Sealing the first helium filled stratospheric balloon with the help of balloon expert Steven Peterzén

In order to minimize the costs of an expedition to Svalbard, this project was executed in collaboration with two other secondary schools, i.e. Sint-Pieterscollege Jette in Belgium and St Paul's School from London. However, each school had its own scientific project.

As retrieving a balloon in the inaccessible environment of Svalbard is not to be expected, a HABduino shield was used to send the data gathered by the Arduino to a receiver.

2. PAYLOADS UNCOVERED

Each payload consists of two microcontrollers, as can be seen in Fig. 3: a first Arduino Uno is attached to the sensors and a micro SD card, a second Arduino Uno is used to drive the HABduino. Though it is possible to hook up all the sensors and the HABduino to a single microcontroller, this was not done due to memory limitations. Because two Arduinos are used, the data has to be transferred between both. This was achieved through serial communication.

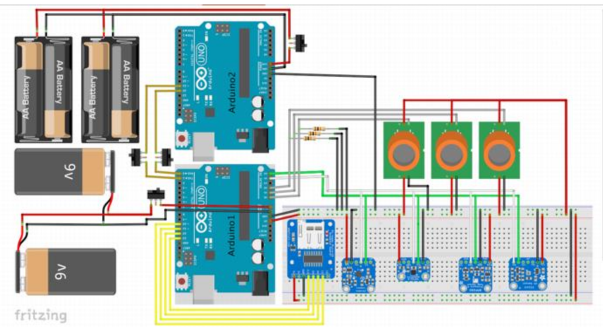

Figure 3. Schematic design of the hardware

The starting point for communicating with sensors is Arduino, an open-source electronics prototyping platform. The Arduino is based on the ATmega328-chip but makes it easier for beginners to start with microcontrollers. The Arduino programming environment is easy to use for beginners, yet flexible enough for advanced users. It is based on the Processing programming environment and can be expanded through C++ libraries. These libraries are used frequently in this project. On the one hand to make it easier to read data from sensors, on the other hand because transferring data between two Arduinos becomes straightforward.

The sensors used in this project are all manufactured by Adafruit. A major advantage of using these sensors is the availability and access to tutorials and libraries on the Adafruit website. The sensors are connected to the Arduino microcontroller by use of an I2C-bus. This makes it possible to drive the sensors with only two wires attached.

There is also a micro SD card on board so data from the sensors can be saved to the SD card as well as be transmitted. There are multiple advantages of using an SD card as a storage device: it is small, light-weight and has a capacity large enough to save a lot of data. The major disadvantage – yet very relevant at Svalbard – is that the SD-card has to be retrieved in order to collect data from it.

Figure 4. Top view of payload 1

3. HABDUINO EXPLAINED

The HABduino project is an open source shield for the Arduino Uno. The main purpose of the HABduino is to send the position and altitude of a high-altitude balloon with radio telemetry as well as data from temperature sensors soldered on to the HABduino. The biggest disadvantage is that the HABduino is not capable of transmitting data from other sensors, like the ones attached to a second Arduino microcontroller. This was overcome by a few software tweaks.

The HABduino board as well as code are fully open source and available on GitHub. The code is written in the Arduino Integrated Development Environment (IDE) and can thus easily be uploaded to an Arduino board. The original code from the developers uses a lot of interrupts – functions that run side by side with the main loop. Because the ATmega328 is a single-core microcontroller, the microcontroller first executes a command of the main loop, then a command of the interrupt, again a command of the main loop and so on. This makes it possible for the Arduino to 'multitask'. A drawback of using interrupts is the relatively high complexity for beginners, even more so if these beginners want to adjust the code.

The data from the second Arduino microcontroller is received through serial communication. To make things less complicated, a library called 'EasyTransfer' is used to manage the transmission of the data. This library is freely available on GitHub. It is able to send data saved in a particular structure with just the use of a simple function. The only problem that can occur using this method is that serial communication might fail while an interrupt is executing. Serial data is a stream of data and while an interrupt is running, this stream cannot be received. This issue has been solved with an if-statement in the code of the HABduino before calling the function to receive data. This means that the Arduino will first execute commands after the if-statement before continuing with the interrupts.

The HABduino stores the data string, that has to be transmitted by radio, in a buffer with the *snprintf()* function. This allows the HABduino to send character after character with the use of the earlier mentioned interrupts, while also gathering the new data for the next data string at the same time. A problem with this function is that support for floating point numbers in the *snprintf()* function has been removed from the Arduino IDE. To maintain the precision of the data, some of the values are multiplied by 100 and converted into long integers rather than just converted into integers. Later in the data processing, this change is reverted.

A disadvantage of the HABduino is the rate at which data is sent. This is caused by a relatively slow baud rate setting in the standard program. Therefore a complete data string, consisting of around 100 characters, takes roughly twenty seconds to be received.

4. RECEIVING DATA

Receiving data was achieved by a technology called Software Defined Radio (SDR). SDR makes it possible to receive and decode radio signals into characters. The only equipment needed is a laptop, a dongle named Airspy Mini and a Yagi antenna. The Yagi antenna was connected to the Airspy Mini with a standard antenna cable.

The Airspy Mini comes provided with software called SDR#. The software translates radio signals received by the Airspy Mini into a spectrum. The user is able to select a part of this spectrum that will be converted into audible sound. The sound produced is then transferred to a program, called Dl-fldigi, with the use of yet another program, Virtual Audio Cable (VAC). VAC makes use of the integrated soundcard of a laptop to record the sound from SDR# and play it back into Dl-fldigi. Dl-fldigi finally converts the sound, which consists of two alternating tones that represent a binary 0 and 1, into readable characters.

An example of a received data string looks as follows: "$$$$$D1,14:22:21,78.147637,16.041252,632,481,954,-6846,93739,2150,61669,584,5749,555,2888,1,300,0,0,0,*F07E". The data from each sensor is separated by a comma.

One of the major drawbacks of this method is that Dl-fldigi needs a strong signal to decode correctly. This means that the transmitter, the HABduino in this case, has to send out a signal strong enough to transmit the many kilometres to the receiver. Consequently, if the balloon were farther away than expected, there is a chance that the antenna would not be able to pick up the relatively weak signal of the HABduino.

5. MEASUREMENTS

The scientific goal of this project was to determine the altitude of the tropopause in arctic conditions. Two balloons were launched with identical payloads to minimize errors. The sensors on board were a humidity sensor and a temperature sensor. The altitude data was taken from the GPS on board the HABduino. These sensors were able to determine the altitude of the tropopause because once the tropopause has been crossed, the temperature starts climbing again and the humidity drops to about 0%. Radio connection with the second balloon was lost while it was descending at an altitude of 15.6 kilometres.

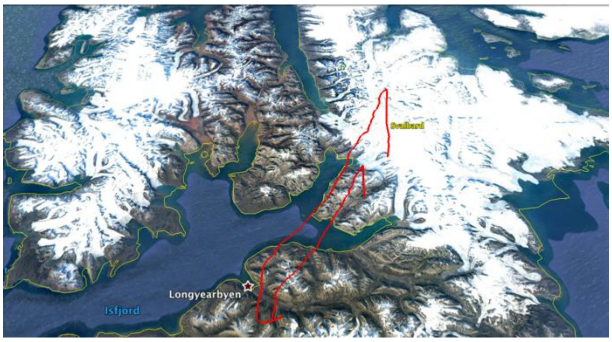

Figure 5. The trajectory of both payloads flown above the Norwegian archipelago Svalbard

The data from the GPS on board gives the opportunity to recreate the trajectory of the two balloons in Google Earth, as can be seen in Fig. 5. They were launched only a few hours apart. It was not possible to launch them simultaneously because there was no equipment available to receive data from two balloons at the same time. Both balloons followed a similar path, but the second balloon did not get nearly as far to the north as the first.

The data clearly shows that the points where the temperature starts climbing and the humidity drops to about 0% do not coincide. This is caused by tiny water drops that are still attached to the humidity sensor while the balloon is already in the stratosphere. The drops take a while to evaporate due to the rotating payload. This has no major impact on the estimation of the altitude of the tropopause because the lack of humidity in the stratosphere is caused by the change in temperature.

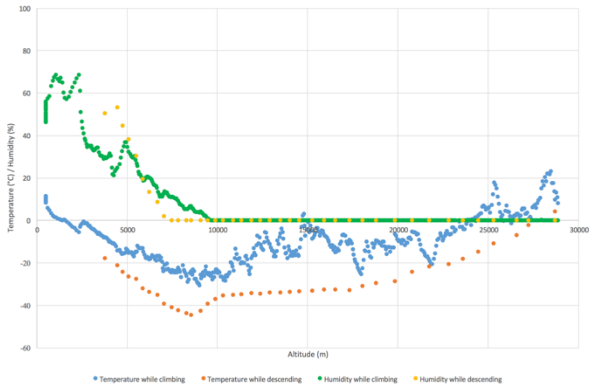

Figure 6. Temperature and humidity versus altitude of both payloads

In Fig. 6, the temperature has a lot of tiny variations. This is again caused by the rotation of the balloon. The sensor heats up when exposed to the Sun's radiation and cools down when not. While descending there were only a few minor variations because of the sunset. This is also the reason why the point where the temperature changes while descending is at a lower altitude than while the balloon was ascending.

It is only possible to make a rough estimation of the altitude of the tropopause because of two reasons: firstly the use of non-professional sensors and secondly the many variations in temperature due to the Sun's radiation. When the average of the data of both payloads is taken, the altitude of the tropopause above Svalbard on September 4, 2016 was between 9000 and 9650 meters.

6. CONCLUSIONS

This paper describes a project carried out by secondary school students. Projects of a similar difficulty level, described in [2] and [3], have been executed by students at Hasselt University. This project shows that it is also possible for even younger students to reach this level. These projects open the door for scientifically and technologically inspired students to an enormous variety of learning opportunities that are scarcely available within a regular secondary school environment.

The open-source platform Arduino was the basis of this project and once again proved to be very student friendly [2] [3].

Previous collaboration [4] between secondary schools showed that organizing the flight and trip together but letting each school fly its own experiment, might be the best approach. Hence partners involved don't need to have a similar level of technological proficiency.

Whatever the benefits of schools cooperating on expeditions abroad like these, time spending at fundraising remains one of the drawbacks.

7. ACKNOWLEDGEMENTS

This project would never have been possible without the expertise of Steven Peterzén, CEO and president of the ISTAR Group, a company that specializes in high altitude, near space balloon launches, launch site development and recovery methods. Thanks to Steven we were able to make use of the Kjell Henriksen Observatory for the integration of our two payloads.

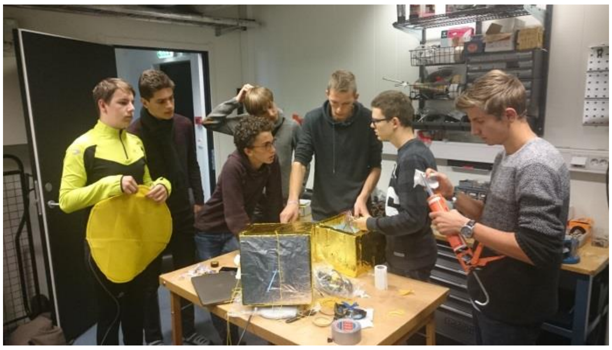

Figure 7. Hands-on work during payload integration at the Kjell Henriksen Observatory

We would also like to thank both team leaders of Sint-Pieterscollege Jette and St Paul's School London, Erik de Schrijver and Ken Zetie respectively. The presence of their teams reduced drastically the costs of our expedition to Svalbard.

8. REFERENCES

[1] Behe, N., Buggenhout, D., Chentouf, Z., Dekock, I., Smet, A., van Moll, C., Van Vreckom, E., de Schrijver, E. (2017). Secondary School Students Designing, Testing and Flying Geiger Counter Equipment to study Atmospheric Gammas over Europe and Svalbard. In *'23rd ESA Symposium on European Rocket and Balloon Programmes and Related Research'*, Visby, Sweden, 11-15 June 2017, ESA Publications Division, European Space Agency, Noordwijk, The Netherlands.

[2] Geeroms, D. et al. (2015). ARDUSAT, an Arduino-Based CubeSat Providing Students with the Opportunity to Create their own Satellite Experiment and Collect Real-World Space Data. In *Proc. '22nd ESA Symposium on European Rocket and Balloon Programmes and Related Research'*, Tromsø, Norway, 7-12 June 2015, ESA SP-730, ESA Publications Division, European Space Agency, Noordwijk, The Netherlands, pp. 643-647.

[3] Joris, T. et al. (2013). Data Logging a Water Rocket with Arduino. In *Proc. '21st ESA Symposium on European Rocket and Balloon Programmes and Related Research'*, Thun, Switzerland, 9-13 June 2013, ESA SP-721, ESA Publications Division, European Space Agency, Noordwijk, The Netherlands, pp. 201-205.

[4] de Schrijver, E. & Geeroms, D. (2011). A Novel Approach to Hands-On Space Education Outreach for Secondary School Students. In *Proc. '20th ESA Symposium on European Rocket and Balloon Programmes and Related Research'*, Hyères, France, 22-26 May 2011, ESA SP-700, ESA Publications Division, European Space Agency, Noordwijk, The Netherlands, pp. 249- 252.